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BASIC PROPERTIES AND USES OF PHOTOCELLS

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/The first eight pages of this article review well-known principles and applications of photocells and give a brief account of historical developments in this field. The following information was taken from the remainder of the article./

Parameters and Characteristics of Photocells

At present, there is no single, thoroughly thought-out system of parameters to provide an exhaustive evaluation of the characteristic properties of photocells of all types, just as there is no single system for determining the corresponding values. Therefore, it is not always possible to compare the results of measurements carried out by different authors. The creation of such a single system is one of the problems in systematizing work on photocells.

Aside from such characteristics as spectral sensitivity, it is essential to know certain physical properties such as the life of the cell, since photocells lose their sensitivity in the course of service. Some very promising types of photocells have proved very unstable and have lost their sensitivity completely after a few months. Similarly, it would be important to know the manner in which the properties of photocells alter with the external temperature. Unfortunately, many of these problems have not been investigated.

Since lack of space precludes a description of the properties of each individual photocell (much of this data can be found in (2) and more up-to-date information in (4), we have tried to summarize the data known to us in the appended table. This lists only Soviet photocells (apart from sulfur and selenium-lead photoconductive cells) as representing all types of photocells and

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being superior to foreign designs in many respects. The only unfortunate exception is the Type TsG (the reasons for this will be explained later). Data on one of the best thermally sensitive elements is given for comparison with the properties of the heat indicators (see column "Heat Receivers" in table).

The need for uniform representation of the properties of instruments differing in the physical principles of their action has made it necessary to resort to some conventions.

Moreover, inasmuch as the concept of the lumen becomes meaningless as a unit of light energy in the invisible regions of the spectrum, the integral sensitivity of photocells intended to work in infrared and ultraviolet regions is given in amperes per watt. The table also includes photocells -- the selenium-thallium (16) and the sulfur-silver (17) with blocking layers -- which, on first showing, seemed very interesting but are not widely used, since they lose their sensitivity spontaneously. In our opinion, this is because they have not been sufficiently worked on, and it is quite possible that in the future these cells will occupy their due place among the others. Finally, it should be pointed out that a question mark in the table means that no data is available.

Some remarks should be made on the contents of the table. In the first place, it should be noted that there may be some inaccuracy in the data. This is because the data was compiled from very extensive material, and, as a rule, no author has taken the trouble to investigate his cell from every angle. For this reason, data on different properties of the same photocell has been culled from different sources, and may refer to essentially different, although nominally identical, cells. The data was checked where possible.

Further, one must point out the special position of the thallous sulfide photoconductive cells, for which, in contrast to the others, the unit of light energy is still the lumen (this has a well-known historical foundation, since work with these cells was done at a time when oxygen-silver-cesium cells predominated).

The table does not give many types of antimony-cesium photocells (STsV-1, StsV-3), as there is no essential difference between these and the STsV-4. No data is available on the behavior of photocells during service. In fact, with a few exceptions (industrial types), there is no reliable data even on sensitivity alterations after 50 hr of use. It will be useful to note that the greatest service duration was observed on the antimony-cesium photocells for sound motion pictures. Cases are known where STsV-4 photocells worked continuously for over 25,000 hours, and the decrease in sensitivity was not more than 10-15%.

Finally, mention must be made of Type TsG photocells, whose sensitivity was reduced to 25% after 50 hr of work, and whose loss in threshold of sensitivity was inferior to that of oxygen-silver-cesium vacuum cells. The physical reason for this is the incorrect amount of inserted gas, which was selected (in 1933) for operation at 240 v, with the object of obtaining as high a sensitivity as possible. This high sensitivity proved to be fictitious however, and the quality of sound production was considerably poorer than it would have been had the operating conditions been properly chosen.

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/Appended table follows. Numbers in parentheses refer to footnotes. Numbers in brackets refer to bibliography./

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PROPERTIES	Working Region of the Spectrum (1) Å	Position of the Spectrum Max Å	Integral Sensitivity: Current mka/lm	Integral Sensitivity: Current a/w	Integral Sensitivity: Voltage(4) (approx) v/ml	Integral Sensitivity: Voltage(4) v/w
TYPE OF PHOTOCELL						
Photocells With External Photoeffect						
Oxygen-silver-caesium, vacuum	4,000-11,000	~8,000	30 (up to 50)		0.1	
Same, gas-filled Type TsG-4 [20]	4,000-10,000	~8,000	250		0.1	
Antimony-caesium, vacuum, Type STsV-4 [20]	3,800-6,200	~4,500	110		0.5	
Antimony-caesium, vacuum, for ultraviolet light [6]	2,000-6,000	4,200	50	~0.1 (2)	0.25	
Photoelectronic Multipliers						
With oxygen-silver-caesium cathode [3] (Kubetskiy system)	4,000-11,000	~7,500	10^6-10^7		10^4	
With antimony-caesium cathode (Kubetskiy system) [19]	3,700-6,000	~4,500	10^{-6}-10^7		10^4	
Photoconductive Cells						
Thallous-sulfide [4]	4,000-13,500	10,000	10^5-10^6		10^3	
Sulfur-lead [4]	5,000-30,000	27,000		Up to 1.0 (3)		Up to 10^3
Selenium-lead [4]	5,000-50,000	25,000; 33,000		Up to 0.1 (3)		Up to 10^2
Photocells, Valve						
Selenium, Type SV-39	4,000-7,000	5,500	500			0.4
Sulfate-thallium [16]	4,000-12,000	9,500	Up to 10,000			0.3
Sulfate-silver [17]	5,000, 12,500	10,500	Up to 8,000			0.3
Heat Receivers						
Thermoelement (Khaze system)	2,000-250,000	--		$3 \cdot 10^{-4}$		10^{-3}

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Max Monochromatic Sensitivity: el/quantum	Max Monochromatic Sensitivity: a/w	Threshold Sensitivity: lm	Threshold Sensitivity: w	Region of Linear Light Characteristic (6) up to	Size of Light Aperture, mm	Internal Resistance (7) ohms	Working Voltage, v	Inertia $\frac{S_{1,000}}{S_{50}} \cdot 100$ in %	Residual Sensitivity in % of Initial: After 50 hr of Service	Residual Sensitivity in % of Initial: After 1,000 hr of Service	Storage Per (9), Yr
~0.01		$\geqslant 5 \cdot 10^{-7}$		1 lm	Dia 40	10^{12}	50-100	100	100	~90	>10
0.1		$5 \cdot 10^{-6}$		0.1 lm	Dia 39	10^{10}	240	~100	~25	~25	?
0.3		$1 \cdot 10^{-7}$		0.5 lm-	Dia 39	10^{10}	50-240	100	100	$\geqslant$ 80	>10
0.1		?		?	Dia 15	10^{14}	50-100	100	100	?	> 5
10^{2}		10^{-9}		10^{-4} lm	~5x3	10^{10}	~1500	100	?	?	?
10^{3}		?		10^{-4} lm	~5x3	10^{10}	1000	100	?	?	?
(5)	?	$>10^{-7}$		0.01 lux	From 2x2 to 5x5	$(1 \div 5) \cdot 10^{6}$	$\leqslant$ 20	10-15	?	?	>1
(5)	Up to 10^{4}	--	$>10^{-9}$	10 μw/sq cm	From 1x1 to 10x10	$(0.1 \div 1) \cdot 10^{6}$	1-100	~100	?	?	?
(5)	?	--	?	?	?	?	?	?	?	?	?
0.3		10^{-4}		1 lm	Dia 39	10^{3}	--	100 (8)	?	?	>1
0.4		?		1 lm	Dia 30	10^{3}	--	100 (8)	?	?	~0.1
0.4		?		1 lm	Dia 20	10^{3}	--	100 (8)	?	?	~0.3
	10^{-3}	--	10^{-5}	?	Dia 3	10	--	0.01	Independent		Unlimited

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FOOTNOTES TO TABLE

1. The zone where the sensitivity of a photocell of the usual form is not yet too small (not less than several percent of maximum).

2. In relation to the integral radiation of the hydrogen tube.

3. In relation to the radiation of a black body at a temperature of 300°C.

4. For photocells with external photoeffect Rn is taken as 5 megohms, as the upper limit possible in practice. For photoconductive cells, Rn = Rf. For value photocells, the noload EMF is the upper limit of permissible voltage.

5. The concept of quantum output has no meaning when applied to photoconductive cells, as it is not possible to draw a line between primary and secondary processes.

6. Only upper limits of linearity already established are given. It is possible that the linearity may, in fact, extend further.

7. For industrial types, the resistance given is that between the electrodes as fitted with the standard socket; for others, when taking steps to counteract leakages.

8. When the resistance of the external circuit is low (less than Rf).

9. The period for which the integral sensitivity is maintained with an accuracy of ±10%.

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